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Forestry Research West

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A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

Forestry Research West

In This Issue

Cover

Research Fisheries Biologist Michael Young, Rocky Mountain Station, is not demonstrating a new way of quenching thirst, he's using a snorkel to sense fish. He has helped author a new publication that compiles information on identifying management options for salmonid habitats. Details begin on page 6.

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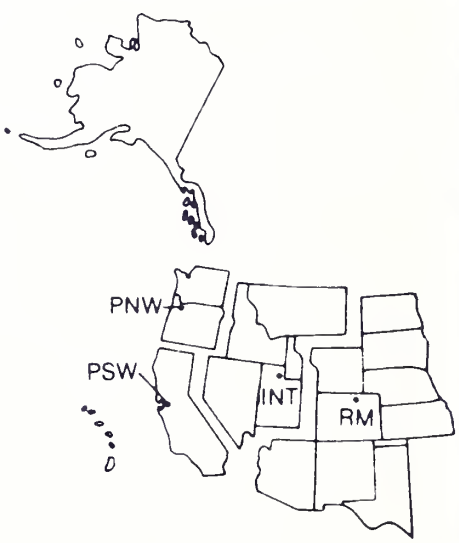


Mission: emission reduction

by Cynthia L. Miner
and Mary F. Burns
Pacific Northwest Station

Concerned about air quality and long-term forest productivity, natural resource managers are considering new ways to achieve objectives traditionally met by prescribed burning. On appropriate sites, prescribed fire remains a preferred tool and is used to meet more objectives than in the past.

Once used mostly to prepare a site for planting or reduce fire hazard, prescribed fire now has applications that include maintaining biodiversity, reducing unwanted vegetation, improving wildlife habitat and forage production, maintaining natural succession of plant communities, and controlling insects and disease. Fire artfully and appropriately applied also may become important in innovative stand and landscape management and restoration in the future. Key for current and future use is the reduction of smoke emissions.

The combustion of forest biomass, the combined material of plants including leaves and bark, produces emissions. Some emissions, such as carbon monoxide, may impact the environment but do not directly impair visibility. Another type of emission, fine particulates, reduces visibility and can be inhaled and deposited in the lungs.

Role of research

Researchers at the Forestry Sciences Laboratory, Pacific Northwest (PNW) Research Station, Seattle, are creating ways to reduce smoke emissions through a research program with other Federal agencies, state agencies, and private industry. Carrying forward research begun by David Sandberg, program manager,

To determine the amount and character of emissions from a prescribed fire, researchers vacuum air samples into monitors and instruments suspended from a cable system strung between steel towers.

PNW Research Station, this group has conducted field studies on 16 National Forests, 2 Bureau of Land Management Districts, 2 Oregon Department of Forestry Districts, 2 California Department of Forestry Districts, and 4 privately owned forests.

The research has contributed to changes in how prescribed fire is used: changes that have resulted in fewer emissions. For instance, from a base-line period of 1976–79 to 1989, emissions from prescribed burns on Forest Service lands fell 44 percent in western Oregon. This reduction, close to the 50-percent reduction goal for emissions in Oregon by 2000, came mainly from fewer acres being burned by land managers; but a portion came from changes in burning techniques.

"As burners become more educated about burning techniques and how to use them," says Janice Peterson, research forester, PNW Research Station, "we expect to see more emission reduction in the future."

The group's technology transfer effort has been led by Roger Ottmar, research forester. Early on Ottmar identified the group's primary clients as (1) fire managers focused on land resources and (2) air resource managers focused on air quality. The group directs its research and development to meet the needs of these managers.

Smoke management

Smoke is managed to meet state and national air quality standards and to avoid nuisances for people near or in view of a burn area. Sites, traditionally, have been burned when weather conditions could transport smoke away from sensitive areas (avoidance) or prevent smoke from accumulating in unacceptable concentrations (dilution). Expanding on these options, the group at PNW Research Station developed emission-reduction techniques.

The techniques are based on three main factors that control the quantity of emissions from a prescribed burn: (1) amount of fuels that could burn (fuel load), (2) amount of fuels that will be burned (fuel consumption), and (3) amount of emissions produced for a specific amount of biomass burned (emission factors). "Total emissions can be reduced if even one of these (main) factors is reduced," Peterson says.

Less fuel

One emission-reduction technique is reducing the amount of fuel before the burn. The more wood taken from a harvested area, the less fuel available for burning, and, consequently, the fewer emissions. Large-diameter wood (greater than 3 inches) can be removed if it is of commercial value. Unmerchantable wood can be piled and burned when conditions will disperse smoke.

Less consumption

A critical approach to reduce emissions is burning only as much fuel as necessary to meet site objectives. If a manager wants to reduce the fire hazard on a site, for example, the removal of small-diameter fuels (less than 3 inches in diameter) may be sufficient; burning large woody material and duff (organic material above the mineral soil) may not be necessary—or desirable.

Large woody material creates seed germination sites, moisture reservoirs during summer drought, places of nutrient exchange for plant growth, habitat for forest organisms, and favorable soil structure. Because of these ecological benefits, managers increasingly desire to keep large woody material on a site—with exceptions, such as heavy concentrations of windthrown trees or mortality from insects or disease.

To decrease consumption of large woody fuels, land managers burn when the moisture of these fuels is high. Under such conditions, small fuels can be completely consumed, but large woody fuels are left mostly intact. Large woody fuels generally have a high fuel-moisture content in winter and spring and shortly after timber harvest.

A helicopter quickly ignites a prescribed fire unit and thereby decreases the amount of smoke emissions.

Duff provides carbon and nutrients to the forest system and protects the soil from erosion and extremes in temperature. In most commercial forests in the Pacific Northwest, duff is less than 2 inches thick. Burning the duff provides a quick release of some nutrients and the long-term loss of others. The role of duff on a particular site and the trade offs of burning versus not burning duff are important management considerations.

From an air quality perspective, duff can contribute 50 percent or more to the total amount of particulates produced in a prescribed fire. The less duff consumed, therefore, the fewer emissions. Duff consumption is reduced by burning when duff moisture is high: during winter, spring, or any time within 5 days of 1/2 inch or more of rainfall.

Another factor in fuel consumption is the way that a fire is started. Janet Hall, research forester, has studied the impact of one type of ignition method on fuel consumption. "Mass fires of high intensity and short duration, such as those that can be generated by helicopter ignition, burn small fuels quickly and completely," Hall says. "Consequently, when the flaming phase of combustion is shortened, large woody fuels and duff are exposed to the flames for a shorter time, and fuel consumption is reduced—potentially by as much as 25 percent."

Consumption during the smoldering phase of a fire can be reduced by either creating a mass fire situation or quickly extinguishing a fire (mop-up). Both techniques reduce the consumption of large fuels and duff. Rapid mop-up also may reduce the amount of smoke settling into valley bottoms.

Lower emission factors

Emission factors cannot be directly influenced. But the composite emission factor, representing the portion of emissions produced in the flaming phase versus the smoldering stage, can be controlled with techniques discussed above under "Less Consumption." By reducing consumption in the dirtier smoldering stage, a resource manager consequently influences the composite emission factor.

Predicting emissions

During planning for a prescribed burn, a resource manager can predict the type and quantity of emissions from the burn. With a procedure developed by the research group, the land manager uses weather, fuel loading, and site information to estimate how much wood and duff will be consumed in the flaming and smoldering phases. Emissions are then estimated by applying emission factors to these consumption estimates. The choice of emission factors is based on the arrangement of the fuels (for example, broadcast or piled), the phase of the burn when consumption will occur, the species of fuel, the location of the burn, and the type of emission (for example, total particulate matter or carbon monoxide).

Fuel consumption models and emission factors have been developed for the most important forest species in the Pacific Northwest. The research group's effort to develop emission factors has been led by Colin Hardy, research forester. He recently has developed emission factors for range vegetation and chaparral brush types.

Technology for managers

Models for estimating fuel consumption and emissions are done with charts (nomographs) or computers. Either format requires fuel and weather as input. Output is an estimate of fuel consumption by stage of combustion. These values are multiplied by emission factors to derive emission estimates. By comparing the impact of various emission-reduction techniques, the land manager can decide the best way to meet prescribed burning and emission-reduction objectives.

The research group is developing four computer software products as decision support for land managers considering prescribed fire under mandates to protect air quality. CONSUME is an interactive, user-friendly program that uses weather conditions to predict

By measuring the reduction of log diameters, scientists determine the amount of woody fuel consumed.

the amount of fuel consumption for prescribed burns. The program helps fuel managers anticipate optimum burning conditions and schedule burns accordingly.

ERPlan is a spreadsheet-based system that will help fuel managers study the impacts of emission-reduction techniques and plan an annual burning program to meet both prescribed fire and air quality objectives. SMS-INFO is a batch-processing model that analyzes prescribed burning records collected by state regulatory agencies and prepares estimates of fuel consumption and emissions for a specified jurisdiction, location, and time.

The fourth tool, EPM, is an interactive model for predicting fuel consumption and emissions from a prescribed burn in conjunction with a dispersion model. EPM is designed as the front-end of decision-support systems that predict the amount and dispersion of emissions.

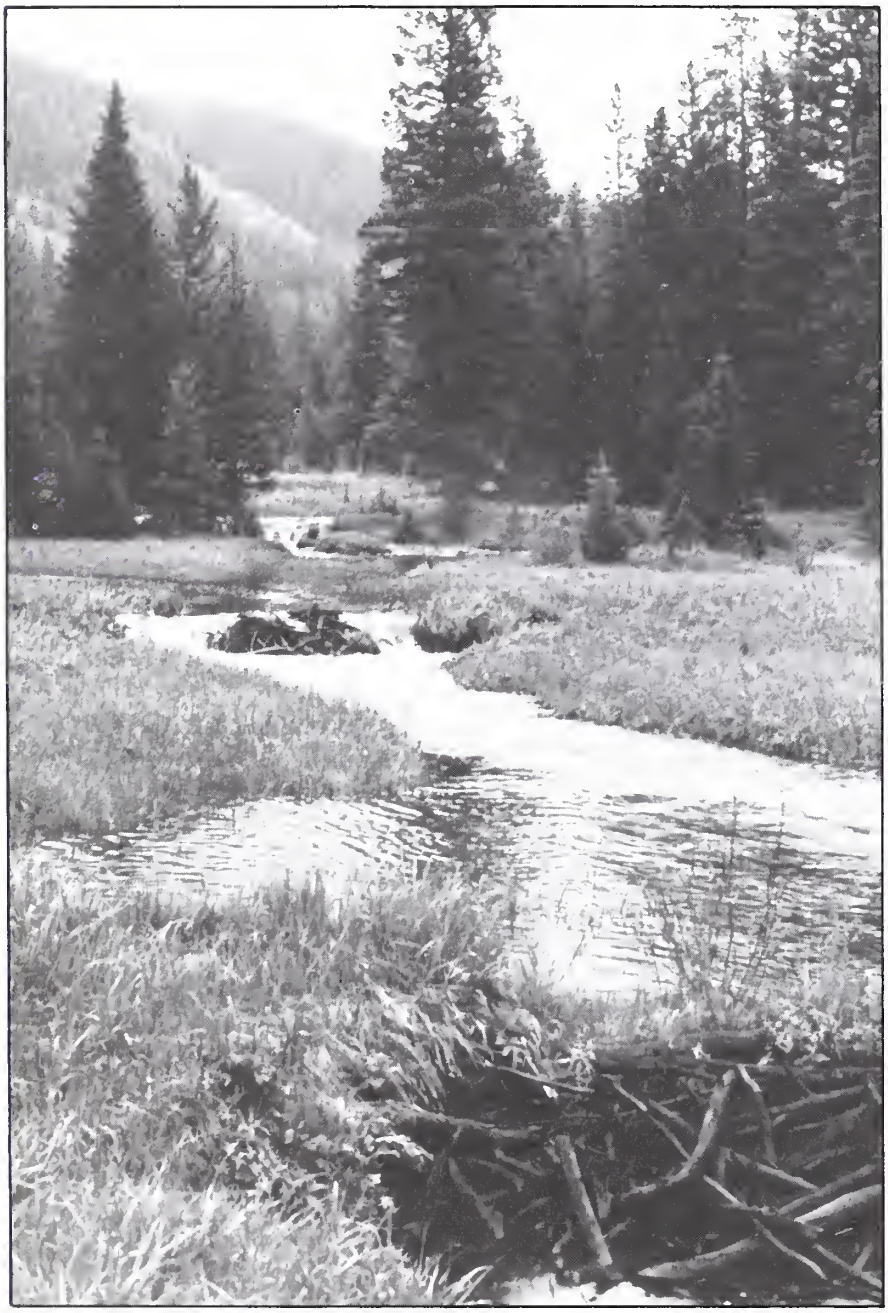
Early versions of these software products are now used in different forms on National Forests and Oregon State lands. For instance, SMS-INFO is used by Oregon to track progress toward its 50-percent goal for reducing emissions. Washington has specified, in recent State legislation, that SMS-INFO will be used to monitor progress in their air-quality program. The first official version of CONSUME is scheduled for release in summer 1991.

Scientists measure how many inches of duff were burned and how deeply the duff was heated.

If you would like a copy of a video providing more detail of the prescribed fire and emissions research at PNW Research Station or would like to be informed when the software products are available, please contact Janet Hall, Forestry Sciences Laboratory, 4043 Roosevelt Way, NE, Seattle, Washington, 98105.

Salmonid-habitat relationships

by Rick Fletcher
Rocky Mountain Station



Beaver dams are an important aspect of trout habitat in the Central Rockies.

"Our current agency fish habitat research program is small compared to the extent of fisheries resources on National Forests, and the technical knowledge required to manage these resources." Research Fisheries Biologist Michael Young was speaking somewhat out of frustration about how much there is yet to learn about fisheries on our National Forests, and the pressing need to provide land managers important information that will help maintain and improve fish habitat. Young, who works at the Rocky Mountain Station's Forestry Sciences Laboratory in Laramie, Wyoming, is part of an effort to identify management options for fish habitat.

Western lands administered by the U.S. Forest Service contain many valuable natural resources, including prominent and highly valued salmonid fisheries. Forest Service land management activities can directly affect a large proportion of these fisheries, since most streams inhabited by these fish originate on National Forests. Presently, the Forest Service is charged with four minimum fish and wildlife objectives:

1) provide for diverse plant and animal communities to meet multiple-use objectives;
2) maintain viable populations of all plant and animal species throughout their existing ranges;
3) accomplish feasible steps to recover threatened and endangered species, and;
4) maintain and improve habitat carrying capacity for species in public demand.

Environmental variables affecting salmonids

Young emphasizes that successful survival and reproduction by aquatic organisms is broadly defined by the physical structure of the environment, the quality of the surrounding waters, and interactions with other organisms. "In streams of the Central Rockies, salmonids are influenced primarily by riparian vegetation, channel morphology, streamflows, deposited sediment, and winter snow and ice accumulation," he said.

Riparian vegetation

One important natural determinant of habitat quality is riparian vegetation. Its influence on streams often is inversely proportional to stream size. Riparian vegetation provides bank stability, trout cover, and organic debris, moderates influences on water temperatures, and contributes energy and nutrients.

Streambank stability

Streambank stability can also affect habitat quality. It is largely dependent on vegetation which creates roughness that decreases water velocity and reduces the erosivity of overbank flows. Though this decrease in water velocity tends to increase the height of flood peaks, bank erosion still declines. Decreased water velocity reduces the ability of water to carry sediment. As a result, riparian zones can be sites of sediment deposition. A well-vegetated reach will likely resist undesirable changes in channel morphology and trout habitat quality.

Electrofishing a turbulent pool to assess fish abundance.

Cover

Salmonid habitat is also dependent on cover—consisting of elements of shade or shadow, and allowing trout to avoid the elements or enemies. Cover frequently consists of three major components: 1) areas of cobble or boulders; 2) overhead bank cover; and 3) pools. Brown trout prefer artificial overhangs close to the water surface in conjunction with tactile stimuli similar to submerged, trailing branches," said Young. "Brook and rainbow trout also prefer overhanging bank cover," he said.

Water temperature

Water temperature has an important effect on salmonids. Forest Service studies show that direct solar radiation accounts for a large percentage of the heat input into Rocky Mountain streams during summer. "And," says Young, "stream temperature is directly proportional to heat input, as affected by solar angle and time of day, and exposed stream surface area. It is inversely proportional to stream discharge. Shading, such as by riparian vegetation, can prevent water from attaining temperatures stressful or lethal to salmonids. Contrary to these findings," he says, "some studies show that unshaded reaches, such as those in and near clearcuts, can actually increase the densities of some species such as the coastal cutthroat trout." It appears that the increased light intensity increases primary production of algae, which augments secondary production of benthic invertebrates, thus boosting the number of drifting insects available to trout.

Large organic debris

Also affecting salmonid habitat is large organic debris (LOD)—any woody material greater than 2.5 cm in diameter. LOD has both physical and biotic impacts on salmonid streams. Physical impacts include changes in stability of streambanks and channels, storage of sediment, dissipation of stream energy, and alteration of channel flows. When LOD is deposited in streams, several variables determine whether the debris will be stably incorporated into the channel. Young explains

that pieces larger than 10 m long and 75 cm in diameter, with both ends and one "face" buried, are the most stable. Debris that had been in place over 5 years, resisted decomposition, and bridged the entire channel generally remained stable. Unstable LOD may cause erosion during high flows by abrasion, and unstable accumulations may result in debris torrents which produce relatively smooth U-shaped channels. LOD can reduce the habitat quality by decreasing channel stability (as described above), by reducing water quality, or by blocking migration. In addition, the heartwood and foliage of some plants, such as western red cedar, can introduce organic chemicals that are toxic to the fry of some fish such as coho salmon. Excessive woody debris can also block the upstream migrations of anadromous fish.

Nutrient and energy effects

Riparian vegetation can act as a sink that removes nutrients and particulate sediment from water prior to entry into streams. "Perhaps the most important role of riparian vegetation," says Michael Marcus, a private fisheries consultant who assisted Young in the effort to identify management options for fish habitat, "is in providing the organic materials that provide the principal energy base for instream biota. Among the characteristics of debris that are important determinants of community composition are the types, sizes, and physical and biochemical compositions of riparian material inputs. These characteristics in turn help define the rates at which debris from the riparian vegetation will decompose in the channel," he said.

Channel morphology

Physical features in stream channels certainly help determine the types and quality of fish habitat. They include stream gradient, water depth, water velocity, substrate, and cover. The morphological and hydraulic characteristics of stream channels are determined by the flow regime and environmental factors such as geology, climate, and vegetation.

Marcus believes that steep drainages in mountain regions of the western United States pose potentials for high erosion and production of deeply incised channels and greatly steepened valley slopes. "To counter these potentials," he says, "natural mechanisms exist that allow streams to adjust channel slopes, which help to protect streambeds. These mechanisms include 1) bed armoring by gravel and boulders, 2) gravel bars that form transverse to streamflows, and 3) log steps that incorporate fallen timber and associated debris into the streambed."

By manipulating the number of dead and dying trees in the streamside forest, managers can influence the hydraulic nature of small streams. Most pools and upstream gravel bars are associated with large streamside obstructions and bends. Based on these observations, a general model to define these relationships has been developed.

Streamflows

Concerning streamflows, scientists know that runoff volumes to streams usually follow seasonal patterns of precipitation. In mountainous headwater streams of the West, snowmelt provides most of the annual streamflow, with flow peaking from May to July. Streamflows can be thought of as having subcritical and supercritical velocities. Subcritical flows exert relatively low energies on banks and beds, while supercritical flows can produce highly erosive force and cause channel damage. "We know that periodic high streamflows that flush fine sediment from the deeper bed layers are necessary to maintain the channel and riparian habitats," says Marcus. "Such flows prevent vegetative encroachment into the channel and encourage plant succession in riparian zones, thereby maintaining and enhancing fishery habitat."

Fine sediment

Most scientists agree that sediment, fine sediment in particular, can have an affect on salmonid habitat. Fine sediment can be transported via saltation along the stream bottom or suspension in the water column. "Some studies suggest that fine sediment can be beneficial to salmonids by contributing to increased invertebrate production," says Young. "However, the transport and deposition of fine sediment can deleteriously affect survival throughout the life history of salmonids," he said. Because murky water absorbs more heat than clear water, increased suspended sediment loads can cause water temperatures to increase. Suspended sediment can also clog and damage

Measuring debris in a stream channel.

respiratory organs. In addition, since salmonids are considered to be sight-feeders, the reduction in light transmission caused by high turbidity may result in less feeding and decreased growth.

"Despite these impacts," explains Young, "salmonids often successfully inhabit streams with seasonally high turbidities, perhaps due to behavioral modifications and to limited exposure to concentrated suspended sediments."

Snow cover and ice

Winter alters trout behavior and affects survival by changing the physical habitat of trout. Among the most obvious changes are reduced water temperature and increased ice formation and snow cover. Young says that declining temperatures in autumn can cause a variety of responses in salmonids. Juvenile salmon and trout usually move downstream as water temperatures decrease. As winter progresses, one or more types of ice may develop. Shelf ice, which forms along streambanks, may eventually cover the entire stream. Anchor ice forms on the stream bottom as the streambed radiates energy upward. Studies show that shelf ice can be beneficial by providing overhanging cover. However, ice can also be associated with mortality. As water temperature increases, anchor ice may detach from the stream bottom and form ice dams—eventually stranding trout. Scientists have also witnessed the killing of trout by the collapse of snowbanks.

Finally, winter conditions affect the feeding behavior of trout and, consequently, their physiology. One study showed that wild brown trout required up to 70 hours to assimilate a 5 gram meal at 0 C. Hatchery trout tended to die in early spring as water temperatures increased—apparently because they lacked energy reserves from the winter to meet the increase in spring metabolic activity.

Stream/watershed relationships

Streams transport and accumulate many nutrients and particulate materials from watersheds. A recent study showed that biotically derived inputs, including litterfall, throughfall, lateral movement, dissolved organic carbon in groundwater, and nitrogen fixation constitutes more than 90 percent of the nitrogen input to a stream. In a related study on a New Hampshire watershed, researchers found that, while evapotranspiration reduced the volume of water flowing from watersheds, annual evapotranspiration rates were essentially constant over a wide range of precipitation and environmental conditions. Stream water chemistries in the undisturbed forests were highly predictable: concentrations of sodium and silica were diluted by streamflows, while concentrations of aluminum, nitrate, hydrogen, potassium, and dissolved organic carbon increased as streamflow increased. Atmospheric inputs to the watershed were the major sources for sulfur, nitrogen, chloride, and phosphorus; weathering was the major source for calcium, magnesium, potassium, and sodium; biological activities

were the major watershed contributors of carbon and nitrogen; and terrestrial plants served as important impaction surfaces for atmospheric sulfur. Overall, the watershed accumulated nitrogen, sulfur, phosphorus, and chloride, while it lost silica, calcium. sodium, aluminum, magnesium, and potassium.

"In a similar study, conducted in northern Colorado," says Marcus, "researchers found that concentrations of bicarbonate, nitrate, calcium, magnesium, and sodium decreased with increasing stream discharge; dissolved organic carbon, hydrogen ions, and phosphate increased with increasing discharge; while ammonium, dissolved organic phosphorus and nitrogen, potassium, and sulfate concentrations showed no trend of change with streamflows."

Impacts of grazing

Livestock grazing is one of the multiple uses of the Nation's forests and rangelands. However, long-term improper grazing is the major reason why so much of North America's rangelands are in poor condition. "Grazing produces a variety of changes in the riparian zone and stream channel that may be detrimental to salmonids," says Young. They include: 1) increased stream temperature, sedimentation, coliform bacteria counts, and channel width; 2) channel and plant community alteration; 3) loss of riparian vegetation; and 4) stream channel trenching or braiding. When comparing heavily grazed streams with lightly grazed or ungrazed streams, the former are generally shallower, wider, and have less overhanging vegetation. Trout populations often increase in response to the exclusion or reduction of grazing. Although successful management of salmonid fisheries on grazed ranges remains a difficult problem, Young says that riparian zones recover relatively quickly, and that undercut banks, important for use by salmonids as cover, may form. In addition, some formerly intermittent streams become perennial within fenced exclosures due to vegetation regrowth, channel aggradation, and reduced soil compaction that lead to increased infiltration rates and storage capacity. Recent research indicates that some grazing strategies such as creating a separate riparian pasture or grazing during winter may be compatible with protecting riparian areas.

Water development projects

Reservoirs and diversion dams disrupt the natural continuum of streams by converting previous flowing water into standing water. Dams can block migration routes for resident stream organisms, alter flow regimes, and change temperature and nutrient patterns in downstream flows. Marcus suggests that downstream dewatering and desiccation are the worst of the possible adverse impacts on the stream and riparian habitats resulting from stream impoundment. "For example," he said, "one study of the potential cumulative effects from microhydroelectric facilities on the Swan River drainage in northwestern Montana indicated that the associated dewatering could eliminate 23, 19, and 6 percent of the high quality

Fire can destroy riparian vegetation and subsequent flooding can wash away trout habitats.

rearing habitat for cutthroat, bull, and brook trout, respectively."

In addition, sediment released downstream during construction of dams may be increased by more than 50 percent over historical sediment loadings, and can significantly reduce fisheries. Reservoirs and diversion dams disperse and disrupt flows and the kinetic energy patterns downsteam. With this dispersal of energy, virtually all sediment carried settles to the reservoir bottom, causing aggradation upstream of the dams. Consequently, waters discharged from reservoirs tend to be nearly devoid of suspended inorganic particles. In unregulated streams, natural peak flows during seasonal or storm-related runoff events mix the upper streambed layers and flush accumulated fine sediment from the deeper layers. But in regulated streams where natural peak flushing flows are greatly reduced, fine sediment can accumulate in the deeper layers, clogging the free flow of water. "This can adversely impact the intragravel habitat important to the survival of benthic insects, incubating eggs, and rearing larvae," says Marcus. "While flushing flows can require high flow rates to remove sediment from deep deposits in some streambeds, these high flow rates sometimes can be very stressful and damaging to biota residents in the stream channel."

Studies show that the best time for implementing flushing flows is when greatest potential benefits to the biological community can be derived. Marcus says that the most reliable method for establishing such rates is to observe the effects of various test flow releases in the stream of interest.

Reservoir effects on temperature

Amplitudes of both daily and seasonal natural temperature regimes also can be significantly altered downstream, depending primarily on the depth of the reservoir outlet. Daily fluctuations, however, tend to increase with distance downstream below the dams, especially as tributary inflows contribute greater influences to the downstream flows. Because natural lakes and reservoirs that have surface water outlets release warmed water relatively soon after heating, temperatures in downstream waters can often be considerably warmer than upstream waters during much of the spring, summer, and early fall. In reservoirs having deep water outlets, heated surface waters accumulate in the upper layers during most of the spring and summer, while cooler, deeper waters are discharged. Then, during most of the fall and winter, cool influent waters tend to be stored in the upper layers of the reservoir, while warmer, deeper layers are discharged. Consequently, compared with temperatures in tributary inflows, water downstream of deep-release reservoirs tend to be cooler during the spring and summer and warmer during the fall and winter.

Downstream nutrient patterns

Another potentially major impact created downstream of reservoirs is the change of natural nutrient input patterns. Construction and filling of reservoirs flood terrestrial environments, leading to leaching of chemicals from flooded soils and from rotting forest debris. Decaying forest materials consume dissolved oxygen and elevate carbon dioxide, nutrients, and dissolved organic materials. As a result, heavy algae growths can be supported, undesirable levels of color and odorous substances may be produced, and conditions that enhance aquatic productivity, or that can be toxic to aquatic life may result. All of these substances become available for discharge from reservoirs, particularly from those with deep-water releases. Consequently, productivities downstream of reservoirs can be enhanced over upstream rates, and this may lead to productivity enhancements in downstream fish populations.

Approaches for managing and evaluating salmonid habitat

Once the variables that constitute salmonid habitat have been defined, the next step is to evaluate the quality of the habitat based on some measure of the variables. Following this, the variables can be monitored through time to detect changes in habitat quality. "It should be noted," says Young, "that the definition of habitat quality is difficult and equivocal, and

Plunge pools created by debris.

that a single definition of quality does not apply to all salmonid species or their habitats."

Most instream flow and habitat investigations endeavor to develop techniques and models through which measures of biological productivity can be described or predicted using a set of habitat variables. Underlying all of the resulting models is the premise that for flow, as well as for other environmental measures, there are definable limits, beyond which conditions become unsuitable for fisheries. Somewhere between upper and lower extremes, optimal conditions exist. Ultimately, after the appropriate relationships are defined, a few well-chosen, easily obtained measurements made for a stream can be entered into a model to predict the stream's potential carrying capacity and/or standing stock of fish. Young stresses that of the available models, the Habitat Quality Index (HQI), referenced in the General Technical Report listed at the end of this article, may best provide reasonable predictions of standing crops, or biomass, for trout in unregulated, coldwater streams in the central Rocky Mountains. Other models have also been developed relating salmonid populations to habitat variables in the central Rockies. These models all show good applicability to the specific range of habitat conditions that they address.

"As the quest for the best salmonid-habitat model continues," says Marcus, "we will likely find in the end that the ultimate solution will be a series of highly specific models developed to address specific habitat related problems for specific types of habitats."

If you would like information on available models, or additional information on salmonid habitat research, contact Mike Young at the Forestry Sciences Laboratory, 222 South 22nd Street, Laramie, Wyoming 82070, (307) 742-6621, FTS-328-0300. A new publication, authored by Marcus, Young, Lynn Noel and Beth Mullan, is also available from the Rocky Mountain Station that describes much of this and related research. Perhaps the most important aspect of this publication is that it provides a comprehensive bibliography of salmonid-habitat research. For your copy, request *Salmonid-Habitat Relationships in the Western United States: A Review and Indexed Bibliography*, General Technical Report RM-188, (see publication ordering cards toward the back of this issue of *Forestry Research West*).

Understanding the "urban" forest visitor

by J. Louise Mastrantonio for Pacific Southwest Station

If you were a social scientist and wanted to be where the action is in wildland recreation, where would you go? Alaska? Northern Minnesota? West Virginia? Maybe. But if you guessed southern California, you'd be right on.

And that is exactly where you will find Sociologist Alan Ewert. Ewert heads a research unit on Wildland Recreation and the Urban Culture at the Pacific Southwest Station's Forest Fire Laboratory in Riverside, California. There, in the foothills of the San Bernardino mountains and only an hour's drive from Los Angeles, the research team has plenty of opportunity to study the impact of large numbers of people on wildlands.

Southern California's four National Forests—the Cleveland, Angeles, Los Padres, and San Bernardino—are all considered by the USDA Forest Service to be "urban" National Forests. That is, they are less than an hour's drive from a population center of more than one million people. Together, these four forests offer one of the best opportunities in the country to study recreation at the wildland-urban interface.

Off-road vehicle use.

The research, begun in 1988 and carried out in cooperation with several land management agencies and cooperating Universities, focuses on the human quotient in forest recreation: how best to communicate with forest users, the causes and solutions to depreciative behaviors such as vandalism and littering, the ethics and values of visitors, and how people's behavior differs as a result of ethnic background.

Unique forests

The concept of "urban" National Forests is relatively new. In 1987, the Forest Service began to recognize that some forests, notably those nearest the Nation's largest population centers, have problems that are unique: large numbers of short-term visitors, visitors that are relatively inexperienced with the out-of-doors, and many more minority visitors—many of whom do not speak English or are illiterate.

At that time, the agency designated eleven such forests nationwide. All were in the West—near the major metropolitan centers of Seattle, Portland, Los Angeles, Denver, Salt Lake City, and Phoenix. These forests supply 20 percent of the total recreation use in the nation's 156 National Forests. Since then, two other forests have been added to the list and others are being considered (see sidebar).

The growing urban influence has many implications for forest management. For one thing, it means a lot more forest visitors with different ethnic backgrounds. "Many of these people are novices in the out-of-doors," according to Ewert. "And their values and behavior may be very different from those of the traditional forest user."

Indeed, some of the behaviors of the "new" forest visitor may be more than a little perplexing to the average forest ranger. An example: In one area used heavily by Hispanics, rangers were perplexed to find used toilet paper thrown in a corner of the outhouse. According to Ewert, this behavior seems much less strange when viewed from the culture of the visitor. In many Hispanic countries, the plumbing will not handle paper and people are expected to put the paper in a basket. If the basket is missing, the person may logically assume that someone forget to replace it.

"URBAN" NATIONAL FORESTS

ARIZONA

Tonto

CALIFORNIA

San Bernardino
Cleveland
Angeles
Los Padres

COLORADO

Pike-San Isabel
Arapahoe-Roosevelt

OREGON

Mt. Hood

PUERTO RICO

Caribbean

UTAH

Wasatch-Cache
Uinta

WASHINGTON

Mt. Baker/Snoqualmie
Gifford Pinchot

In another situation, a researcher saw a visitor throw a beer can into the woods. When asked why he was doing that, the visitor responded that he thought it was a *good* thing...because transients could pick up the cans and return them for money.

In yet another case, two men were arguing over the tossing of trash in the forest. When the first man persisted in dumping the debris, the second man left, returned with a 350 MAGNUM, and "persuaded" the first man not to dump the trash.

Understanding such behavior is important, not only to help managers prevent vandalism and other "deviant" behaviors, but also to help new and relatively inexperienced visitors get the most out of their recreation experience.

Implications

Although the research has been going on for only two years, the payoffs have been almost immediate. Many studies are short term and results are already pouring in from more than twenty different studies. Some of the implications of the findings to date:

- Cultural background (Black, Hispanic, Anglo, Asian) is important in determining a visitors' attitude and behavior but subculture may be even more important: age, education, country of origin, length of time in the United States.

Picnicing.

For example, in a study in the Angeles National Forest, all Mexican and Hispanic groups had stronger motivation for sunbathing, meeting new people, and activities involving eating and drinking (picnicking) than did Anglos. And Mexicans and Hispanics born outside of the United States showed a stronger motivation for hiking, learning about nature, experiencing new things, and being with family than did those born in the United States. (Study by Dr. David Simcox at California State University, Chico, and Dr. Robert Pfister, California State University, Pomona.)

- A large percentage of visitors to urban National Forests are newcomers to forest recreation. Their attitudes and expectations may be quite different than those of more traditional users. In a two-year study by Pfister and Dr. Ron Hodgson at Chico State, most visitors (64%) to San Gabriel Canyon in the Angeles National Forest were found to be Hispanic and live within an hour's drive of the forest.

Many of these people (40%) were first-time visitors to the National Forest. More than half made their first visit within the last three years and most learned about the area from friends or family. In addition, the mean size of groups was eight people—indicating a more highly socialized experience than is traditional in the National Forests.

- In keeping with national recreation trends, most visits to the urban National Forests are short term. A study in the Inyo National Forest found that most visitors were on long weekends, with stays of one to five days. (Study by Dr. Perry Brown and Marty Lee at Oregon State University, Corvallis, with the Pacific Southwest Station.)

- Forest managers may need to develop new ways to communicate regulations and informational material. Many urban forest visitors do not speak English and may even be illiterate. Traditional methods of communication—signs, brochures, bulletin boards—will obviously not be effective in reaching these people.

What helps

In fact, recreation managers (city, county, state, and federal) believe the most effective way to prevent and control depreciative behavior is to increase visibility of park rangers or other authority figures and to step up law enforcement efforts. (Study by Dr. Dan Dustin at San Diego State with the Pacific Southwest and Pacific Northwest Research Stations.)

The research has also been useful in destroying some of the common "myths" managers have about managing people, according to Ewert. One of those is that you automatically solve the problems by hiring minorities for field work. He's not against hiring minorities, but says "you don't necessarily solve inter-ethnic or cultural differences by hiring a member of that ethnic minority for law enforcement. The visitor looks at the person as a Forest Service employee first and a member of their ethnic minority second."

It is important, however, to have a research team that is both bi-cultural and bi-lingual. This helps in both study design and data collection. Many studies are conducted through personal interviews in the field and researchers need to be able to speak the principal language of the forest visitor.

Ewert also believes in a strong effort to communicate research findings to land managers. "In the past, the *modus operandi* of forest managers has been to educate the user. Another way of looking at this is to educate the agency as to what the user wants. It's a kind of customer service. There are a lot of different customers out there. Up to now, the ones that have pretty much set the agenda for us have been white and middle class. Now we're finding that's not always the typical user."

The research unit has a strong outreach program designed to communicate with managers. Researchers participate in forest-level workshops, attend conferences, and plan to conduct a Social Aspects and Recreation Research Symposium in October 1991 at Lake Tahoe. There, researchers and managers will have an opportunity to discuss recreation impacts at the wildland-urban interface.

The project also publishes a news-Letter of recent findings. To get on the mailing list for "Recreation Research Update," or for other information, write or call: Project Leader, Wildland Recreation and the Urban Culture, USDA Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, California 92507. Phone: (714) 276-6285. For information about the conference, contact Dr. Debbie Chavez, Research Social Scientist with the unit.

Target shooting.

Building better bushes

by David Tippets
Intermountain Station

From dry, sun-soaked, south slopes in the Great Basin Desert to snow-nourished plateaus near timberline in the Rocky Mountains, sagebrush covers more land than any other plant. West of the 100th meridian, sagebrush identifies the single most common type of ecosystem, yet no plant has been more maligned as an enemy of civilization. Long seen as a rival of grass for livestock, people plowed, chopped, chained, rolled, sprayed, and burned it with a vengeance for the last century. But as defiant as the coyote that sleeps in its shade, sagebrush soon returns to its empty niche and reigns over its kingdom while human conquerors struggle to maintain their toehold on the land.

Surviving the taming of the West and flaunting progress, sagebrush endured until the second century of National Forest management and new initiatives toward more ecologically based management. With "Change on the Range" and "New Perspectives" emphasis on biodiversity and a more balanced range of resource values, range enemy number one, sagebrush, will soon change its image. It's no longer just an adversary to livestock forage. As the land area for wildlife habitat shrinks, sagebrush will become more important than ever on big-game winter range. On some damaged lands, sagebrush will restore the natural structure of the ecosystem and provide

Scientists working on the shrub improvement project seal paper bags over sagebrush flower stalks, enabling them to control breeding and test hybridization.

microsites needed for a return to natural diversity.

"Few range plants are more aggressive, productive, and persistent than big sagebrush (*Artemisia tridentata*)," Plant Physiologist Bruce Welch of Intermountain Research Station's Shrub Sciences Laboratory said. "However, we cannot think of any range plant that needs more forage quality and palatability improvement than big sagebrush."

Sagebrush, plants of the genus Artemisia, in North America comprise a subgenus, Tridentatae, of which taxonomists separate up to 23 different species. Tourists driving across the West for the first time would see little difference as they cruise past one species to the next. But for wildlife, the difference between species can be the difference between health or starvation. For plant geneticists, the variability within just one species provides years of challenge in a quest to develop better bushes. And as a bonus to geneticists, the species are genetically similar enough that most can cross pollinate and produce hybrid offspring.

Variability means survival

Mother Nature made tremendous variability within sagebrush. Variability allows sagebrush to adapt and survive in a changing environment. The same variability provides Forest Service geneticists with an opportunity to accelerate the natural selection process and breed plants to pre-adapt them to fire, drought, or climate change.

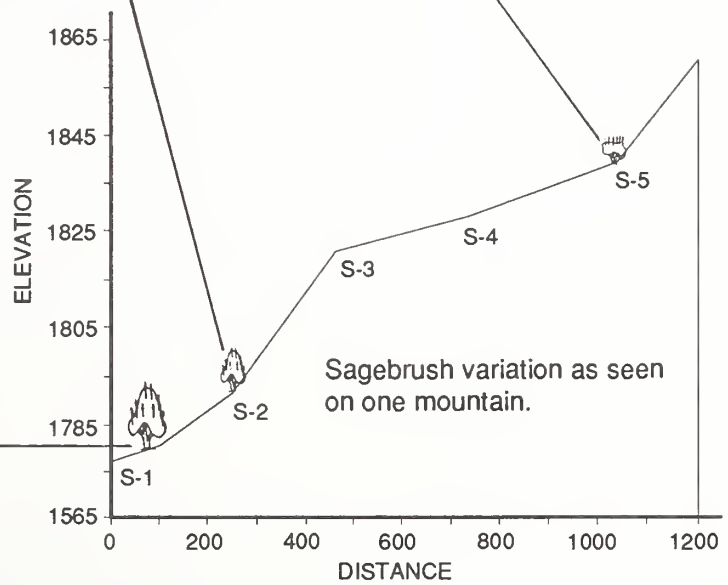
Not all species, and not all sagebrush plants within a species, deserve the bad reputation that humans traditionally assign. Some plants produce palatable and nutritious browse for both wildlife and livestock. " 'Hobble Creek' big sagebrush is highly preferred and can raise energy level, protein, phosphorous, and carotene in the diets of wintering domestic sheep or mule deer," Welch said, describing a variety of sagebrush growing just south of the Provo, Utah, laboratory.

Evergreen shrubs that often protrude from snow that buries grass, sagebrush can provide more available as well as more nutritious forage than dried grass. But sometimes the most nutritious plants contain chemical compounds, monoterpenoids (essential oils) and coumarins, (a substance having a vanilla-like odor—used for flavoring and in perfumery), that make them unpalatable, and sometimes the sagebrush most palatable to animals is not the most nutritious. Plants of both varieties or even different species with desirable attributes can cross-breed in nature, producing plants that have the best combined qualities of nutrition and palatability.

Breed a super bush

Size, productivity, site adaptation, drought tolerance, and the ability to survive fire add complexity to the variation within plants and species of plants that can potentially cross breed to produce a "super" bush. In nature, site potential often makes it difficult to separate genetic potential from the influence of the environment where scientists first identify the desired trait.

Starting in the early 1970s, scientists with the Intermountain Station's Shrub Sciences Laboratory began collecting seed from what appeared to be genetically superior parents and growing the seeds in a uniform garden to allow them to identify real genetic variation. Scientists will study the characteristics of the plants growing in the same environment of the uniform garden for a multiple-generation test to make sure the selected plants have the genotype for the traits selected. Using some of the same techniques that produced superior wheat and corn, Forest Service geneticists will breed superior sagebrush.



Sagebrush variation as seen on one mountain.

Shrub improvement project leader E. Durant McArthur transfers pollen of one subspecies of big sagebrush to another to produce a new hybrid offspring for testing.

After several generations of testing, seeds from genetically superior super bushes will be given to government and commercial nurseries to produce plants for range improvement or disturbed land reclamation.

Super hybrid sagebrush may combat the cheatgrass invasion and occupation of the western range. An exotic annual, cheatgrass formed a partnership with wildfire to convert millions of acres of biologically diverse rangelands into virtual monocultures. Cheatgrass grows to maturity and reproduces early in the spring before native grasses have hardly started. The fine, tinder-dry annual grass provides flash fuel for rapidly spreading wildfires that kill much of the native vegetation not adapted to fire. Then in the ashes, cheatgrass seeds germinate where native grass seed burned on the stem. The process has repeated for decades, creating a fire and cheatgrass cycle that has baffled scientists and managers until recently.

Fast shrinking habitat

Aldo Leopold recognized the problem when he wrote "Sand County Almanac" in 1949. "It is impossible fully to protect cheat[grass] country from fire. As a consequence, the remnants of good browse plants, such as sagebrush and bitter brush, are being burned back to higher altitudes where they are less useful as winter forage . . . The habitable wintering belt is narrow [and is] . . . now fast shrinking under the onslaught of cheat[grass] fires," he wrote.

Leopold described a sagebrush-grassland ecosystem where the sagebrush is not adapted to fire. But in the Shrub Sciences Laboratory's gardens grow plants whose roots sprout new growth after fire and that are tolerant of the droughts that frequent cheatgrass country. Shrub Improvement Project Leader E. Durant McArthur estimates that in 15 to 20 years they will provide seeds to nurseries for a nutritious and palatable shrub that will sprout new growth from the roots after fire.

Geneticist Stewart C. Sanderson "fixes" sagebrush flower buds in acetone for later chemical and chromosomal analysis.

Break the fire cycle

By establishing sagebrush seedlings on cheatgrass range after fire, managers will restore the structure of a natural native community. Microsites created by the sagebrush will encourage native plants to move back in, bringing with them much of the wildlife that abandoned the cheatgrass-dominated ranges. The transformation of the community back to a more natural state, including later developing plants that stay green longer in summer, will help managers to break the cheatgrass-fire cycle.

For land managers not concerned about cheatgrass but needing to rehabilitate winter range, the shrub scientists developed a new hybrid to optimize sagebrush qualities for production of palatable browse and resiliency to browsing. Scientists are already observing characteristics of the second generation of this plant and predict that this new super sagebrush will be available in 7 to 10 years.

Like broccoli and pork rinds

"It's like combining ice cream with spinach, or in the values of President Bush, like combining broccoli with pork rinds," McArthur said, describing qualities of the new shrub for wildlife food. Traditionally, bitterbrush and mountain mahogany starred as the "ice cream" plants on big game winter range. But according to McArthur, they lack the same potential for genetic improvement into the super browse that sagebrush has because they are adapted to a smaller range of environments and geographic sites.

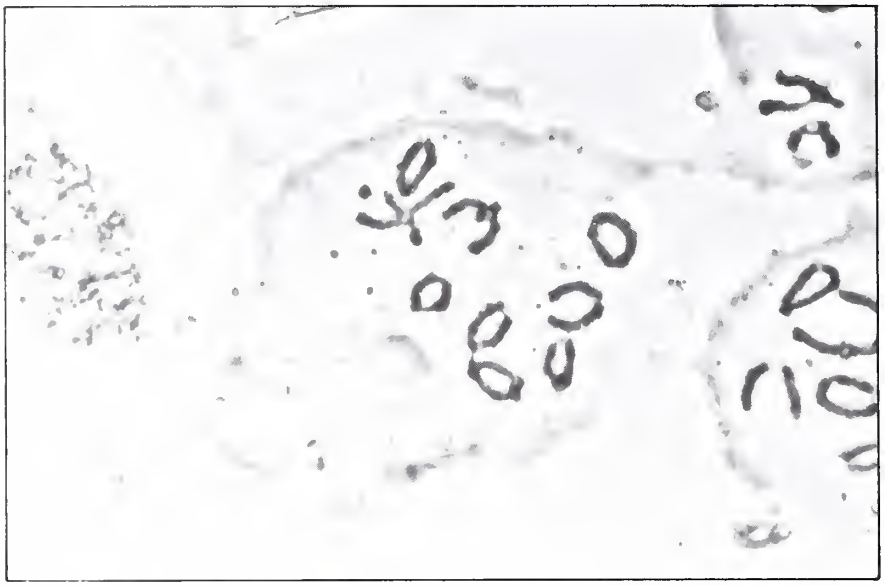
"The dream," McArthur said, "is to someday be able to have the biotechnology to move and combine genes with precision genetic engineering."

Sagebrush members of the highly evolved Compositae family that have many individual flowers per floret and many florets in each inflorescence, produce an enormous amount of seed from each hybridization experiment.

Throw away the cookbook

The dream in shrub research, like the dream in space travel, produced knowledge and useful technology long before humans walked on the moon. In the quest for a better bush, scientists discovered new things about sagebrush physiology, morphology, and taxonomy. Research is revealing complexity about sagebrush ecosystems that suggests to land managers that it's time to throw away the cookbook for quick-and-easy range improvement. No single recipe will make a good stew with the tremendous variety of sagebrush.

Starting in 1949, Joe Pechanec, the first Station scientist to extensively investigate sagebrush ecosystems, stressed that before successfully managing sagebrush-grassland communities, range managers must understand the condition and trend of the plant communities. But in the following decades sagebrush communities were oversimplified in classification systems. Scientists now identify 43 sagebrush-grass habitat types and estimate that they may eventually classify over twice that number.



Chromosomes of low sagebrush, Artemesia arbuscula, *seen through a microscope during meiosis, show the chromosomes paired in characteristic ring, rod, and x shapes. Pairing of chromosomes in meiosis allows gene exchange in hybrids.*

New thinking emphasizes understanding ecological status and the desired future condition. Knowledge gained in shrub improvement research will help managers understand both the ecological status and potential value of these extremely diverse and complex communities. For example, one current study investigates the dynamics of plant hybrid zones where different subspecies or varieties of sagebrush naturally come together.

Storm the sinuses

A simple and inexpensive application of technology developed in sagebrush research can be applied by managers to help evaluate sagebrush communities.

Coumarins and monoterpenoids, chemical compounds that serve as palatability cues to browsers, exhibit useful traits. Coumarins floresce under ultra-violet light, producing a blue glow. UV or black light kits can be assembled that are portable and can be used in the field as an indirect indicator of sagebrush's palatability. Some people, after gaining experience with the black light test, develop the ability to evaluate palatability just by smelling monoterpenoids from crushed foliage. In an extremely unpalatable plant, characteristic monoterpenoids flow from crushed leaves like menthol from an inhaler and storm through the sinuses, leaving no questions about why sagebrush is named after sage.

The smell of sage and the blueish-colored vistas that greeted early pioneers that crossed the Intermountain area on their way to California or Oregon left strong impressions recorded in many journals. For modern travelers yearning to get closer to the land, it may be less obvious that the Intermountain West, by nature's rules, is a shrubland—and that of all the shrubs sagebrush is the king.

In the land that was tall-grass prairie, genetically superior corn now thrives. In the land that was once short-grass prairie, genetically superior wheat now blows in the wind. In the land that was once Mississippi-floodplain forest, hybrid poplars grow 13 feet in a year to produce pulp for paper. But in the land that was once sage as far as the eye could see, a genetically superior sagebrush could return much of the landscape back to a more natural state.

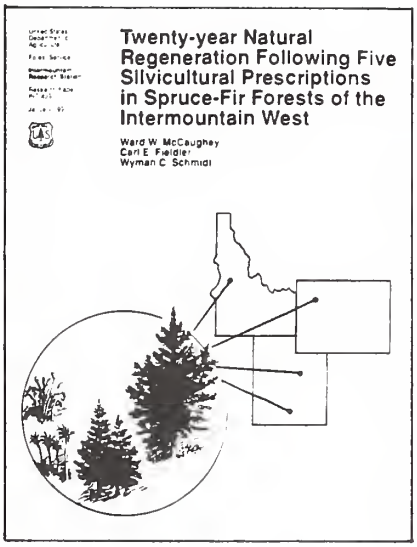
New from research

Investigating the impact of dwarf mistletoe on western larch stands

Dwarf Mistletoes, the most serious tree disease in North America, have been a common topic of research for years. Yet information has been absent on the spread of dwarf mistletoe in stands of western larch (*Larix occidentalis* Nutt).

To fill this gap, scientists conducted a 20 year study from 1968 to 1988 on a thinned, pure stand of western larch in the Coram Experimental Forest in Montana. The objectives of the study were to determine the rate of growth, intensification, and spread of the disease in stands thinned to three levels of stocking.

The last 10 years of the study, including results, are described in *Upward Advance, Intensification, and Spread of Dwarf Mistletoe in a Thinned Stand of Western Larch*. Request Research Note RM-504 from the Rocky Mountain Station.



Partial cutting best for spruce old growth

Silviculturists Ward W. McCaughey, Carl E. Fiedler, and Wyman C. Schmidt learned after analysis of 20 years' data from four National Forests that no single combination of site preparation was good for natural regeneration of spruce-fir forests in the Intermountain area. They discovered that partial cutting and minimal disturbance of the site generally produced the best natural regeneration.

High-elevation study sites in the Payette, Teton, Uinta, and Dixie National Forests showed that prescriptions for spruce-fir forests must be site and Forest specific. Even though results differed for these four widely separated Forests, the authors list six important factors that managers must consider in properly managing this forest type.

Since spruce-fir forests are frequently riparian zone types and they also compose much of the remaining old-growth forest in the Intermountain area, this publication provides scientific data to help managers make decisions in areas of public concern.

Request *Twenty-year Natural Regeneration Following Five Silvicultural Prescriptions in Spruce-Fir Forests of the Intermountain West*, Research Paper INT-439, from the Intermountain Research Station.

Proceedings—cheatgrass and shrub management

This publication includes the papers presented at the sixth symposium sponsored by the Shrub Research Consortium devoted to the biology and management of western wildland shrubs.

Because of their economic importance during the last century, forest lands and grasslands stole the show. But if importance was measured by the number of acres of habitat types in the mountain west, shrublands represent a much larger constituency. In this age of concern over biological diversity and consideration of noncommercial values, shrubs and shrublands will likely get the attention that they deserve ecologically.

Papers discuss a wide range of topics from big-game winter range improvement to ways to break the cheatgrass-fire cycle.

Request *Proceedings—Symposium on Cheatgrass Invasion, Shrub Die-off, and Other Aspects of Shrub Biology and Management*, General Technical Report INT-276, from the Intermountain Research Station.

Future timber demand expected to rise

As directed by the Forest and Rangeland Renewable Resources Planning Act (RPA), forest and rangeland resources must be assessed every 10 years, and timber is one of the many resources being appraised.

The recently completed assessment predicts rising demands for timber products, as have past assessments, due to increases in U.S. population, income, and economic activity. Yet resource specialists realize this prediction may be challenged by three happenings: global change, recycling, and the continued establishment of pine plantations in the South.

For a copy of *An Analysis of the Timber Situation in the United States: 1989–2040* request General Tecnical Report RM-199 from the Rocky Mountain Station.

Multiresource management of ponderosa pine forests

A recent conference, the first of its kind on multiresource management of ponderosa pine forests, strove to break new ground in communication between natural resource managers, resource specialists, academicians, agency researchers, and the concerned public on what is the best management strategy for our national forests.

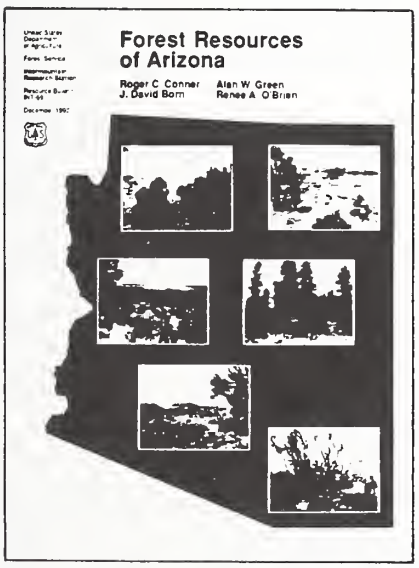
In hopes of uniting under a common goal, the different groups came together to share papers on their various approaches to ponderosa pine forest management. The papers were grouped into six main themes: 1) distribution and growth of forests, 2) factors affecting forest resource outputs, 3) forest diseases, environmental pollutants, and other stresses, 4) wildlife habitat concerns, 5) integrating public concerns into forest resource management, and 6) multiresource management systems.

For a copy of the conference proceedings, request *Multiresource Management of Ponderosa Pine Forests*, General Technical Report RM-185 from the Rocky Mountain Station.

Arizona forest resources

Contrary to the cactus landscape image held by many, forests cover 19.9 million acres of Arizona, representing a significant state and national resource. Much of Arizona's forested land is outside the boundaries of National Forests.

Authorized by the Renewable Resources Research Act of 1978, Forest Service scientists and technicians from the Intermountain Research Station inventoried all of the non-National Forest land in the State. Their data, when combined with information from the National Forests, provide a scientific basis for more ecologically sound forest policies and decision making.



This report is valuable for anyone concerned about the orderly development of the State, or the wise management of its resources.

Request *Forest Resources of Arizona*, Resource Bulletin INT-69, from the Intermountain Research Station.

Publications about research at Cascade Head

Citations for over 200 publications have been compiled that describe research conducted on the Cascade Head Experimental Forest and Scenic Research Area on the Siuslaw National Forest, Oregon. The publications span from 1934 to 1990. These publications include papers, theses, and reports. An index allows cross-referencing with keywords.

Request from the Pacific Northwest Station Research Publications of the Cascade Head Experimental Forest and Scenic Research Area, Oregon Coast Range, 1934 to 1990.

Ecology of insects in California chaparral

Information on the interrelationships or dynamics among insects in the chaparral community is scant. Equally limited is published information on the biology of the chaparral insects. Information on insects associated with certain chaparral species is found in works by Essig (1958) and by Furniss and Barr (1975). By and large, however, entomologists have been preoccupied with describing and studying insects that enjoy a more economically important status.

Interest in chaparral insects from the standpoint of community ecology was stimulated by the International Biological Program (IBP) that was active from 1967 to 1974. In 1970, the U.S. National Science Foundation funded a Mediterranean Scrub Project that provided a comparative analysis of Chilean and California scrub vegetation and insects in these two communities.

This paper describes a small portion of the ecology of insects in chaparral ecosystems of California, and includes a review of earlier studies.

To request this paper ask for Research Paper PSW-201, titled *Ecology of Insects in California Chaparral*. It is available from the Pacific Southwest Station.

Research and management of annosus root disease

Root diseases caused by fungi are considered by the Forest Service to be among the most damaging diseases of conifers in western North America. Research and development on control of these diseases is considered to be high priority.

Annosus root disease caused by the fungus Heterobasidion annosum (*Fomes annosus*) has been recognized as a worldwide problem in conifer forests for decades, and a substantial body of information and literature has accumulated on its biology, impact, and control.

There is an increasing awareness and concern among managers about the importance of this disease in our western forests, and scientists and pest managers have accumulated a substantial body of knowledge over the last decade or two on the management of annosus root disease. This symposium should also indicate what further research and development are needed to improve the manager's ability to reduce losses from these and other serious root diseases of Western forests.

Proceedings of the Symposium on Research and Management of Annosus Root Disease in Western North America, General Technical Report PSW-116, is available from the Pacific Southwest Station.

Managing diseased firs

True firs (*Abies* spp.) are economically and ecologically important in the West. They also are particularly susceptible to disease. Root diseases, stem decays, and dwarf mistletoes cause tree mortality, growth loss, and cull. The authors of this publication summarize all that is currently known about true fir disease management in Oregon and Washington. They discuss the biology, recognition, and management of major diseases and offer a range of silvicultural management strategies to reduce disease-caused losses in true fir stands.

The publication has detailed instructions on recognition of diseases including color photos. Management strategies include type of regeneration, precommercial thinning, prescribed burning, fertilizing, and final harvest.

Request *Rx for* Abies*: Silvicultural Options for Diseased Firs in Oregon and Washington*, General Technical Report, PNW-252, available from the Pacific Northwest Station.

Prediction of fuel moisture during the 88 Yellowstone fires

Roberta A. Hartford and Richard C. Rothermel, scientists at the Intermountain Research Station's fire laboratory in Missoula, MT, measured fine fuel moisture during days of rapid spread of the North Fork Fire, and discovered a significant adjustment needed in both the BEHAVE fire prediction system and fire behavior analyst's tables. While predicted moisture content for grass fit the parameters of prediction models used, the moisture content of lodgepole pine litter did not. To a great extent fire spread was in the pine litter, which did not recover fuel moisture at night as fast as other fine fuels, helping explain the radical night fire behavior that challenged firefighters.

This publication provides scientific insight into the extreme fire behavior of the historic 1988 fire season.

Request *Fuel Moisture as Measured and Predicted During the 1988 Fires in Yellowstone Park*, Research Note INT-396, from the Intermountain Research Station.

To order any of the publications listed in this issue of *Forestry Research West*, use the order cards below. All cards require postage. Please remember to use your Zip Code on the return address.

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3. (87-136) *Fire History and Pattern in a Cascade Range Landscape*, General Technical Report PNW-254.
4. (87-253) *Specifications for Structural Range Improvements*, General Technical Report PNW-250.
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3. *Fuel Moisture as Measured and Predicted During the 1988 Fires in Yellowstone Park*, Research Note INT-396.
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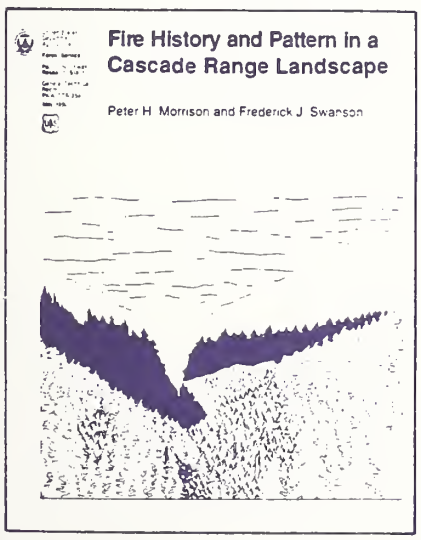
Fire history and patterns

The natural regime of wildfire provides a reference point for interpreting the effects of forest management practices on the patterns of forest vegetation across the landscape. These patterns profoundly affect wildlife, drainage basin hydrology, and characteristics of large-scale ecosystems.

This publication reconstructs fire history from 1150 to 1985 based on tree-ring analysis. The authors analyze forest stands and map fire patterns in two areas in the Cascade Range of Oregon. The stands revealed a highly variable fire regime. The steep, dissected, low-elevation area experienced frequent fires (rotation of 95 years). The other area was cooler, moister, and less steep and had less frequent (rotation of 149 years) and predominantly stand-replacement fires. Old-growth forest conditions have persisted on some sites through numerous fires over many centuries. This publication provides details of how the authors dated fires and established patterns.



Request *Fire History and Pattern in a Cascade Range Landscape*, General Technical Report, PNW-254, available from the Pacific Northwest Station.

Monitoring pileated woodpeckers

The pileated woodpecker, the largest woodpecker in North America, is found in highest densities in old-growth conifer forests. The bird's need for large dead trees for nesting, large hollow trees for roosting, and dead woody material for foraging make it susceptible to impact from short-rotation forestry. To protect the pileated woodpecker, National Forests provide management areas of standing and downed dead wood. These areas need to be monitored for their effectiveness.

Populations of pileated woodpeckers can be monitored by examining (1) density of breeding pairs, (2) reproduction, and (3) presence or absence of birds. This publication describes monitoring methods of locating pileated woodpeckers, including imitating pileated woodpecker vocalizations, identifying nest and roost trees, and finding foraging signs.

Request *Techniques for Monitoring Pileated Woodpeckers*, General Technical Report PNW-269, available from the Pacific Northwest Station.

Fences, gates, troughs, ponds, and more

The construction and maintenance of structural improvements, such as fences, water developments, and access trails are essential to grazing management. The authors provide the best information from many sources for structural range improvements in a practical and readable handbook for ranchers, contractors, resource managers, and anyone who plans, installs, or maintains structural improvements.

This handbook has specifications, descriptions, and drawings for the array of structural improvements that might be made on rangelands. The section on fences, for instance, includes barbed-wire fences (standard post and wire, let-down, suspension, and rock-jack), woven-wire fence, electric fence, buck-and-pole fence, log-worm fence, block-and-pole fence, and log-crib fence. Other sections discuss gates, cattle guards, stiles, water developments, stock ponds, and livestock access trails.

Request *Specifications for Structural Range Improvements*, General Technical Report, PNW-250, available from the Pacific Northwest Station.

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